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Recycling MIL-H-46170 Hydraulic Fluid to Extend Fluid Service Life

March 1995

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This report documents the laboratory efforts in proving that used hydraulic fluid could be recycled by removing contaminants and mixing with new fluid. Once the used fluid has been filtered to remove solid particulate contamination and de-humidified to bring the moisture content below 500 ppm water, it can be mixed with new fluid in a 75:25 ratio to bring the fluid mixture up to specification performance. The recycled used fluid by itself could not pass the foaming characteristic requirement thus requiring re-inhibition. Instead of adding more anti-foaming agent to the fluid, the decision was made to mix recycled fluid with new fluid to provide the re-inhibition effect. Mixing in new fluid results in an enhancement of all additive performance and eliminated any possible problems with adding too much or too little anti-foaming agent. These efforts set the standards for evaluating commercial recycling units that can recycle hydraulic fluid on a large scale and also establish doctrine for successfully extending the service life of used hydraulic fluid.

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Section 1 Introduction and Background

At the request of the Defense General Supply Center (DGSC), the Fuels and Lubricants Division of the Mobility Technology Center - Belvoir has investigated the possibility of recycling hydraulic fluid. In an effort to reduce the waste stream of POL products generated by military units, The DGSC Hazardous Materials Minimization Office provided funding from the Defense Environmental Restoration Account (DERA) to not only demonstrate that hydraulic fluid could be recycled, but to also evaluate commercial recycling technology. Most often, even though hydraulic fluid can contain significant water and particulate contamination, the additive package which provides the fluid's desired performance remains in tact. If hydraulic fluid can be recycled by removing contamination, and the clean fluid determined to retain sufficient performance capabilities, a reduction in the POL waste stream would result because the recycled fluid could be returned to service.[1] Recycling the fluid will not only reduce disposal costs, but also significantly reduce new fluid procurement costs.

In demonstrating the recyclability of hydraulic fluid, this investigation was limited to MIL-H-46170 hydraulic fluid (FRH).[2] The objective of the investigation was to characterize any loss of performance of the used fluid, identify effective means of recycling the fluid, and demonstrating satisfactory performance of the recycled fluid. Two issues were addressed in this effort. First, the fluid was evaluated in the laboratory to determine the viability of recycling hydraulic fluid. The data gained from this investigation provides the baseline for evaluating commercially available recycling technology. Not only must it be proven on a laboratory scale that the fluid can be recycled but also that large quantities generated by maintenance units and depots can be recycled using commercial technology. The effort in the laboratory sets the stage for evaluating the viability of recycling on a large scale.

Section 2. Technical Approach

In demonstrating that hydraulic fluid can be recycled and returned to service, three tasks were performed. First, used fluid was evaluated against specification requirements to identify any loss of fluid performance. Second, techniques were developed for removing the water and particulate contamination present in the used fluid. Finally, techniques were developed for returning the recycled fluid to specification performance. Table 1 provides a summary of the performance requirements as specified in MIL-H-46170. These requirements must be met by the recycled fluid before it can be successfully returned to service.

Table 1. MIL-H-46170 Fluid Performance Requirements

PERFORMANCE TEST	MIL-L-46170
Oxidation/Corrosion ASTM D4636, #3	168 hrs @ 135°C vis. chng < 10% acid # chng < + 0.30
Corrosion Inhibition ASTM D1748	100 hrs min
Galvanic Corrosion FTM 5322	10 days
Low Temp Stability FTM 3458	72 hrs @ -54°C
Pour Point ASTM D97	-60°C min
Viscosity @ 40°C ASTM D445	19.5 cSt max
Viscosity @ 100°C ASTM D445	3.4 cSt min
Viscosity @ -40°C ASTM D445	2600 cSt max
Viscosity @ -54°C ASTM D445	report
Solid particle Count MIL-H-46170	10,000 max @ 5-25 micrometers
Solid Particle Count [illegible]-H-46170	250 max @ 26-50 micrometers
Solid Particle Count MIL-H-46170	50 max @ 51-100 micrometers

Table 1. MIL-H-46170 Fluid Performance Requirements (continued)

PERFORMANCE TEST	MIL-L-46170
Solid Particle Count MIL-H-46170	10 max @ over 100 micrometers
Acid Number ASTM D664	0.2 gm KOH/gm max
Elastomer Swell FTM 3603	-
Nitrile	0% - 3%
Fluorocarbon	0% - 1%
Fluorosilicone	0% - 2%
Polyacrylate	0% - 2%
Polyurethane	0% - 1%
Evaporation Loss ASTM D972	5% max
Steel on Steel Wear ASTM D4172	0.3 mm max @ 10 kg load
Steel on Steel Wear ASTM D4172	0.65 mm max @ 40 kg load
Foam Characteristics ASTM D892	65 ml max
Water Content ASTM D1744	500 ppm max
Flash Point ASTM D92	204°C min
Fire Point ASTM D92	246° min
Storage Stability FTM 3465	12 months

The task of recycling the hydraulic fluid is one of removing unwanted contaminants and treating the fluid to bring performance back to specification requirements. The effects of contamination in a hydraulic system can be disastrous. Solid particle contamination in the fluid can cause wear and jamming. Additionally, a domino effect can take place because wear of the surfaces exposes clean metal which is then subjected to corrosive attack if moisture is present in the system. It is vital in recycling hydraulic fluid that particulate and moisture contamination be removed otherwise the additives in the fluid will be hampered in their ability to provide protection.[3]

Removing the particulate contamination in the laboratory was relatively straight forward but time consuming. The fluid was first centrifuged to remove any large sediment contamination. The centrifuged fluid was then subjected to a series of successively smaller filters (5.0 microns, 0.8 microns, 0.45 microns) until the particle count fell below the maximum allowed by the specification.

One technique for removing water contamination involves dilution of the hydraulic fluid with a water-immiscible solvent that will separate the water into an immiscible layer then co-distilling the off the water and solvent. This technique is recommended if large amounts of water are present. Used fluid that was obtained from Aberdeen Proving Ground was found to contain only 728 ppm water thus a different technique was employed, which although simpler, could prove to be time consuming.

The used fluid was simply heated to 109°C for a period of time. The amount of time required depended on the volume of fluid being de-humidified and degree of water contamination. One liter of fluid containing less than 0.1% water required only 2 hours of exposure at 109°C. Fluid containing greater than 0.5% water required 24 hours to de-humidify 1 liter. Heating the fluid to 109°C was sufficient enough to drive of any water yet not stress the fluid thermally. In most cases the water content was reduced to half of the maximum (500 ppm) allowed. While the techniques used in the laboratory proved effective, they are not the techniques of choice for recycling hydraulic fluid on the premises of maintenance units and depots. The technology required must allow for high volumes in a short amount of time. In most cases, this can only be accomplished through filtering technology that removes all types of contamination.

Section 3 Results

Table 2 below summarizes the results of all testing performed on the used and recycled fluids. Comparison of the results summarized in this table with the requirements identified in Table 1 indicate that the used fluid does not provide adequate performance in Low Temperature Stability, Water Content, Foaming Characteristics, Fire Point, Particle Count, and Evaporation Loss. The recycled fluid, however, demonstrated an immediate improvement in Low Temperature Stability, Water Content, Particle Count, and Evaporation Loss on simply removing the particulate and water contamination. The recycled fluid still did not exhibit satisfactory performance in Foaming Characteristics or Fire Point.

Table 2. Fluid Performance — Used and Recycled

TEST	USED FRH	RECYCLED FRH
5308 ACID NO.	0.22	0.36
5308 COUPON WT CHNG	PASS	PASS
5308 Δ VISCOSITY	9.6%	3.9%
HUMIDITY CABINET	PASS	PASS
GALVANIC CORROSION	PASS	PASS
LOW TEMP STABILITY	FAIL	PASS
VISCOSITY -40 °C	2506 cSt	2494 cSt
VISCOSITY 40 °C	15.7 cSt	16.4 cSt
VISCOSITY 100 °C	3.8 cSt	4.2 cSt
POUR PT	Below -60°C	Below -60°C
FLASH PT	211°C	208°C
FIRE PT	233°C	224°C
WATER CONTENT (PPM)	728	278
FOAMING	80/0, 30/0, 60/0	90/0, 30/0, 60/0
4-BALL WEAR	0.382 mm	0.355 mm
ACID NUMBER	0.25 mg KOH/mg	0.15 mg KOH/mg
PARTICLE COUNT (MICROMETERS)	127,347 (5-25) 32 (26-50) 2 (51-100) 0 (OVER 100)	1,257 (5-25) 19 (26-50) 1 (51-100) 0 (OVER 100)
EVAPORATION LOSS	5.95%	4.36%
ELASTOMER SWELL	—	—
NITRILE	1.78%	1.45%
FLUOROCARBON	0.46%	0.39%
FLUOROSILICONE	2.04%	2.4%
POLYACRYLATE	1.06%	1.44%
POLYURETHANE	0.37%	-0.26%

Given that the recycled fluid failed only the foaming characteristics, only minor treatment of the fluid would be required to bring the fluid within specifications. Instead of adding additional anti-foaming agent to solve the problem, new FRH from an unopened can was added to the recycled fluid. Two mixtures were created to identify the maximum and minimum fluid ratios. New FRH was mixed with recycled FRH in 25:75 and 50:50 ratios. These fluid mixtures were evaluated against the same performance criteria with results summarized in Table 3 below.

Table 3. Performance of Recycled FRH Mixed with New FRH

TEST	25:75 FRH MIX	50:50 FRH MIX
5308 ACID NO.	0.13 mg KOH/mg	0.21 mg KOH/mg
308 COUPON WT CHNG	PASS	PASS
5308 Δ VISCOSITY	-1.34%	-4.42%
HUMIDITY CABINET	PASS	PASS
GALVANIC CORROSION	PASS	PASS
LOW TEMP STABILITY	PASS	PASS
VISCOSITY -40 °C	2473 cSt	2183 cSt
VISCOSITY 40 °C	16.4 cSt	17.0 cSt
VISCOSITY 100 °C	3.9 cSt	3.8 cSt
POUR PT	Below -60°C	Below -60°C
FLASH PT	212°C	210°C
FIRE PT	230°C	236°C
WATER CONTENT (PPM)	324.5	342.1
FOAMING	55/0,30/0 50/0	55/0,30/0 50/0
4-BALL WEAR	0.34 mm	0.37 mm
ACID NUMBER	0.21 gm KOH/gm	0.15 gm KOH/gm
PARTICLE COUNT (MICROMETERS)	Not Necessary	Not Necessary
EVAPORATION LOSS	3.84%	3.30%
ELASTOMER SWELL	—	—
NITRILE	1.67%	2.24%
FLUOROCARBON	0.19%	0.81%
FLUOROSILICONE	1.62%	1.91%
POLYACRYLATE	0.71%	2.53%
POLYURETHANE	-0.50%	-0.11%

As can be seen, both fluid mixtures passed all performance requirements except the Fire Point. The foaming characteristics tested below the maximum allowed in the specification. Evaporation Loss, Flash Point, Fire Point, and corrosion/oxidation stability (5308 test) all improved with the addition of the new fluid. Neither fluid mixture, however, passed the Fire Point requirement. The 25% mixture exhibited a Fire

Point of 16°C below the minimum while the 50% mixture exhibited a Fire Point 10°C below the minimum. Although some improvement in Fire Point occurred, there seems to be no significant performance improvement of the 50% mixture over the 25% mixture.

Section 4 Conclusions

While recycled FRH does not meet all specification performance requirements, it can be treated with new FRH to improve fluid performance to specification standards. Although adding new fluid to the recycled fluid did not bring the fire point completely up to the specification requirement, the fluid mixture did meet the flash point and all other requirements. A loss in Fire Point of 10-16°C does not imply a significant loss in fire resistance. Keeping the flash point up to specification standard indicates the fire resistance of the fluid remains predominantly in tact. In evaluating the merits of recycling hydraulic fluid, the negative aspects are simply the slight loss in fire point whereas the positive aspects are the reduction in waste stream and associated costs.

Costs of recycling will be limited to the recycling process itself, with no expenses going toward procurement of additives to extend the service life of the fluid. Treating the recycled fluid with new FRH precludes the difficulties that are inherent in trying to add new additives to a formulated fluid. There will be no danger of adding too much additive and causing instability or too little additive and not meeting performance requirements. Since hydraulic fluid cannot be recycled indefinitely, some procurement of new fluid will always take place, thus a ready source of new fluid to mix with the recycled fluid will always be available. Even though the recycled fluid must be mixed with new FRH, significant savings will result because the waste stream will be reduced thus lowering disposal costs and procurement volumes of new fluid will lessen.

The efforts discussed in this report were limited to proving on a laboratory scale that FRH could be recycled and returned to service. This is just the first step prior to implementing a hydraulic fluid recycling program throughout the military. The next phase of this investigation is to evaluate commercial recycling technology to verify that the fluid can be recycled to meet specification performance on a large scale. Once successful commercial units have been identified, a field test of the units themselves and the recycled fluid in actual vehicles will be conducted. In addition, efforts will also be aimed at performing oil analysis on the used and recycled fluids to better identify the types of solid particulate contamination found in the used fluid and removed in the recycling process.

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WRIGHT PATTERSON AFB
OH 45433-7103

AIR FORCE WRIGHT LAB
1 ATTN WL/MLBT
2941 P ST STE 1
WRIGHT PATTERSON AFB
OH 45433-7750

AIR FORCE WRIGHT LAB
1 ATTN WL/MLSE
2179 12TH ST STE 1
WRIGHT PATTERSON AFB
OH 45433-7718

1 AIR FORCE MEEP MGMT OFC
615 SMSQ/LGTV MEEP
201 BISCAYNE DR STE 2
ENGLIN AFB FL 32542-5303

1 SA ALC/SFT
1014 ANDREWS RD STE 1
KELLY AFB TX 78241-5603

1 WR ALC/LVRS
225 OCMULGEE CT
ROBINS AFB
GA 31098-1647